

REMARKS

By this Preliminary Amendment, claims 1-9, 11-13, 18-21, 25, 29-30 and 32-35 have been amended. Claims 10, 28 and 31 have been canceled. Claims 37-39 have been added.

Claim 1 has been amended to include the feature “applying a variable gain function to said volume control signal in order to determine the system gain signal for applying to the digital audio signal” and wherein the variable gain function is dependent on the volume adjusted parameter signal. Support for this can be found, for example, in the description of the operation of the circuit of Figure 5 and more generally in the first and third paragraphs of page 6 and previous claim 10. A corresponding method claim 37 has been added and the pending method claims have been made dependent on this claim.

Amended claim 1 is directed to a gain determining stage for amplifying digital audio signals in which the gain stage receives a parameter of the signals such as its peak signal level envelope, adjusts the parameter dependent on a volume control signal, for example, multiplying the two signals and generating a system gain signal by applying a variable gain function (for example the circuit of Figure 5) to the volume control signal. The variable gain function of Figure 5 is a limiter which reduces the system gain that would otherwise be applied by the volume control signal if a further control signal dependent on a parameter of the digital audio signal (e.g., peak level) and the volume control signal exceeds a threshold. Thus, the adjusted parameter signal represents the anticipated gained signal peak level, before operation of any limiting. If this signal exceeds the threshold, then limiting is applied by the variable gain function to the volume control signal in order to determine a gain signal for applying to the digital audio signal. When applied to the audio signal, the gain signal amplifies this according to the volume control signal but limited if needed dependent on the peak level of the pre-amplified audio signal.

By making the output or system gain depend on both the user provided volume control and the input signal parameter (e.g., peak level), the volume control and dynamic

range signal processing functions such as limiting are combined. This reduces the number of large silicon real estate components such as multipliers required to implement these two functions, which are particularly important in low cost portable digital audio signal processing applications such as those provided to MP3 players and the like. A further advantage of incorporating the user provided volume control signal at this point is to reduce the dynamic range of the input signal or parameter of the input signal (because the input signal is not first multiplied by the volume signal as in prior art arrangements), thereby reducing the number of bits required for the gain selector stage.

This combination of volume control and the dynamic range functionality provided by the application of an appropriate variable gain function which, in turn, is also dependent on the volume control signal, is not known or disclosed in the prior art cited in the UK Search Report submitted in an Information Disclosure Statement filed on January 7, 2005. For example, Ishimitsu, U.S. Patent No. 5,369,562, uses volume control to select a particular input/output gain characteristic (one of two tables of gain curves), but does not adjust the input signal parameter (the peak level) dependent on the volume control signal. This can be seen in Figure 1a, where the output from the input signal level detector 3 is coupled directly to a table selection section 5 in order to determine the gain of a variable gain amplifier 1.

Thus, in Ishimitsu, the choice of input/output characteristic is dependent on a speaker output or volume control 6 used in a subsequent power amplifier for example (see column 3, lines 13-16). Thus, the volume and the compressing functions are kept separate in Ishimitsu. The volume control signal contributes only to the selection of the input/output characteristic and not the gain level itself. The gain level is dependent on the input signal level from the detector 3 as applied to the selected characteristics. The peak level signal from the detector 3 is not adjusted (e.g., multiplied) by the volume control signal. This is different than the present invention, which, in one embodiment, multiplies the user provided volume control signal with the input signal parameter. The adjusted

peak signal level envelope signal therefore affects the gain applied, and hence the volume; for example, as explained with reference to Figure 4. This allows the early determination of the peak level of the audio signal as multiplied by the volume gain signal, and therefore, if necessary, the application of limiting for example. This, in turn, allows the volume and dynamic processing functions to be applied together, rather than having the two applied by different circuits with the associated disadvantages of additional components, and in particular, more expensive components requiring higher bit widths.

The Pioneer document, DE 422 1428, is based on the same Japanese priority application as Ishimitsu, and according to the English language abstract and drawings, does not add anything to this document. It is therefore submitted that the amended claims are novel over these two prior art documents. Further, because the volume control signal in these prior art documents is used to select the input/output characteristic, but is not used to generate the gain in conjunction with the selected characteristic, there is no suggestion to take this additional step, and indeed, the placement of the volume control at the power amplified output stage teaches away from utilizing it at this earlier amplifier stage.

The other Pioneer document, EP 1296450 is an analog amplifier which would not be suitable for amplifying digital audio signals as required by the claims. Analog and digital amplifiers have different design considerations, for example, in terms of structural complexity, dynamic range, noise and so on; and so the skilled person would not consider analog amplifier designs in order to assist in solving problems related to digital amplifier design. Furthermore, a variable gain function dependent on an applied volume control signal is not disclosed. In contrast, there is a single transfer or gain function (provided by the Zener diode 5B), which is not dependent on the volume signal. There is circuitry for enabling or disabling the limiting function provided by the Zener diode dependent on a selected volume level, but this is not the same as the variable gain function itself being dependent on the volume signal. Furthermore, given the presence of a separate volume

control, i.e., outside the limiting circuitry, the disclosed approach teaches away from the presently claimed approach and it is therefore believed that the amended claims are both novel and inventive over the Pioneer document.

Lubbe, U.S. Patent Application No. 2001/0055400, discloses an analog audio processing system with a digital volume control. The volume control signal (6) is added to a digital log peak signal (42), which resulting signal (8) is then applied directly to control the gain of an amplifier (2) in the signal path. There is no variable gain function dependent on the signal 8 and the volume control signal 6, either external or internal to amplifier 2.

Therefore, the arrangement in Lubbe does not anticipate the amended claims. Furthermore, Lubbe is a completely different approach to that claimed, and uses analog amplification and so would not be relevant to considerations of implementing digital amplification for the reasons already noted above.

Telex, WO 98/47224, discloses a software based digital audio signal processing algorithm which includes factoring into the gain selection a crest factor sensitivity which is determined dynamically as the ratio for the peak to average signal level. There is no disclosure of volume control. It is therefore submitted that this document is not relevant to the amended claims.

Sony, JP 2001/320793, discloses automatic gain adjustment, with the aim being to avoid the need for manual regulation of volume level. This teaches against the aims of the present invention which aims to incorporate manual volume adjustment with other audio signal processing function such as limiting and compression. It is therefore believed that this document is also not relevant to the amended claims.

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For the foregoing reasons, the amended claims are submitted to be distinguishable over the prior art cited in the UK Search Report.

Prompt examination on the merits is respectfully solicited.

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